

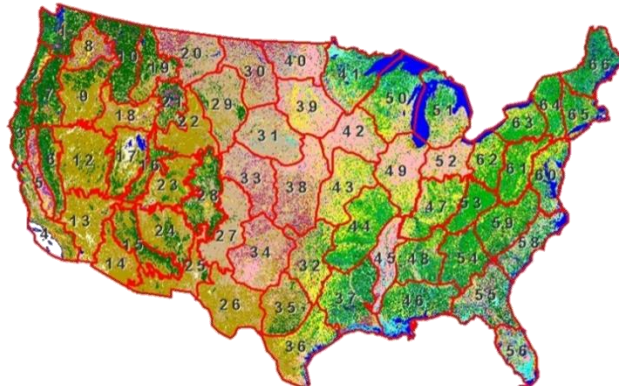
# Scenarios and LULC Modeling for the LandCarbon Project and Beyond – A “producer’s” perspective on land cover drivers

**Terry Sohl**

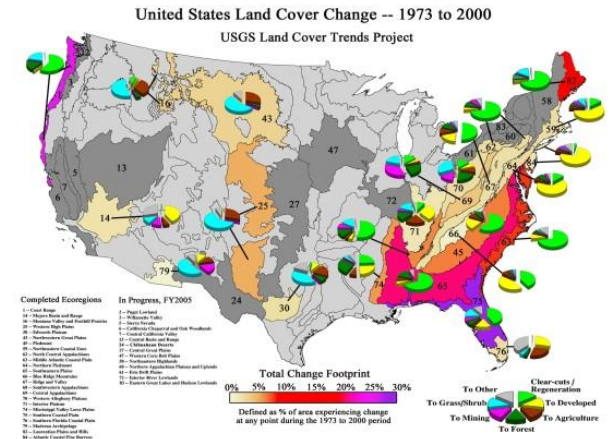
**USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD**

# Land-cover Modeling at USGS EROS - History

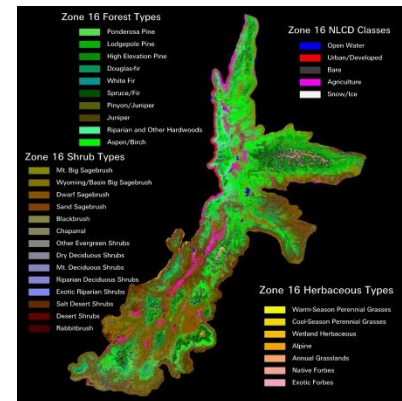
- Land-use and land-cover (LULC) modeling at EROS began ~2004
  - Time when several national-scale land cover mapping efforts were underway
  - NASA ROSES proposal for impact of LULC change on weather/climate (Loveland, Pielke Sr., Sohl, Steyaert)



## Land Cover Trends



LandFire



National Land Cover Database (NLCD)

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# Basic Structure – USGS EROS “FORE-SCE” Model

**FOREcasting SCEnarios of land-cover (FORE-SCE) model: A modular approach to drivers and issues of scale:**

- **Non-spatial “Demand” module provides overall proportions of LULC change for future dates (*Answers “How Much?”*)**
  - Largely dependent on “top-down” drivers of LULC change, including those that are non-spatial
  - Very flexible in methodology to produce demand
    - We’ve used extrapolations of historical data, economic models, targeted scenario construction, integrated assessment models
    - Can use either regional proportions of LULC, or complete transition matrix
- **“Spatial allocation” component ingests “demand” and produces spatially explicit LULC maps (*Answers “Where?”*)**
  - Largely dependent on “bottom-up” drivers of LULC change
  - Requires spatially explicit supporting data
  - Flexibility to operate at multiple spatial and thematic resolutions

# USGS LandCarbon Assessment

## Research Questions:

- What is biological carbon sequestration capacity and greenhouse gas fluxes under multiple future scenarios?
- How effective are management practices on short- and long-term carbon sequestration and GHG flux mitigation?
- How effective are changes in land use on carbon sequestration and GHG flux mitigation?
- What might be the most effective and/or feasible mitigation strategies?
- How might mitigation strategies impact other ecosystem services?

## Scope:

- Five primary ecosystems: forests, shrub/grasslands, croplands, wetlands and aquatic (rivers, lakes, coastal waters) systems
- Two types of assessment: baseline (“present-day”) and future projection (to 2050)
- Carbon storage and sequestration; fluxes of CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub>
- Effects of natural and anthropogenic processes (e.g. climate change, wildfire, land use change, and land management activities)

Ecosystems ♦ Climate ♦ Energy and Minerals ♦ Natural Hazards ♦ Environment and Human Health ♦ Water



# **“Demand” and Scenario Construction**

## **Regional Scenarios Consistent with SRES** *Components of Scenario Construction*

**Population, economic growth, technologic innovation  
environmental awareness, governance, regulatory regime,  
biophysical conditions, natural resource base**

### **LULC Histories (LC Trends)**

- Recent historical estimates of gross and net LULC change
- Gains, losses
- Conversions
- Ecoregion-based
- Summary reports and driving forces

### **IAM's (IMAGE 2.2)**

- Integrated drivers (climate, demographics, economics, etc.)
- National and gridded agriculture and forestry
- National land management (biofuels, fertilizer use, energy demand, etc...)

### **Expert Judgment**

- Global scenarios (SRES, RPA, MA, CCSP, RCPs)
- External modeling (ICLUS, RPA, FASOM-GHG)
- National inventories (NLCD, CENSUS, AGCENSUS, FIA, NRI, PAD)
- Downscaling Literature (Gridded, EURURALIS, ATEAM)



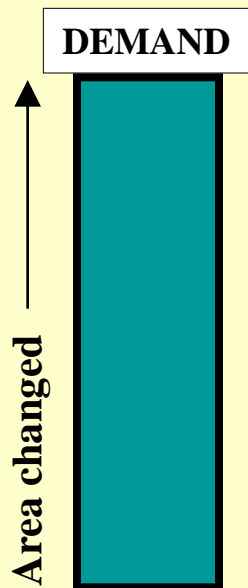
# FORE-SCE: Patch-based Spatial Allocation

**FORE-SCE uses a unique, patch-based spatial allocation procedure**

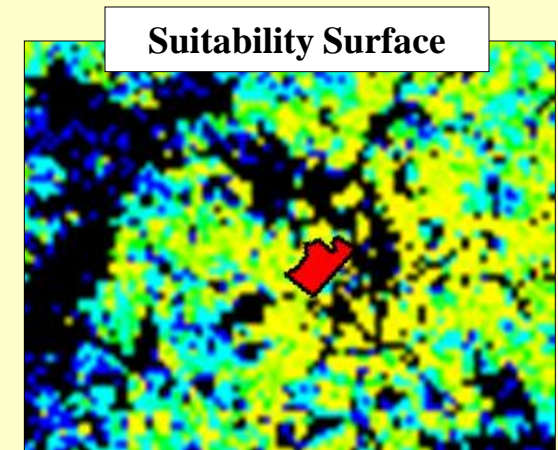
- An individual patch of a new LULC class is placed on the landscape, and the area of LULC change is tabulated.
  - Patch characteristics defined by historical, regional data
- FORE-SCE loops back and repeats the process, with patches continually placed on the landscape, until DEMAND for LULC(x) is met
- Once DEMAND for LULC(x) is met, the process continues with LULC(x+1), until all land cover types have been modeled

**Two user-selected options in FORE-SCE for patch placement:**

1. Patch grow algorithm (patches “grow” from seed pixel) (*slower*)
2. Patch library (below) (*faster*)

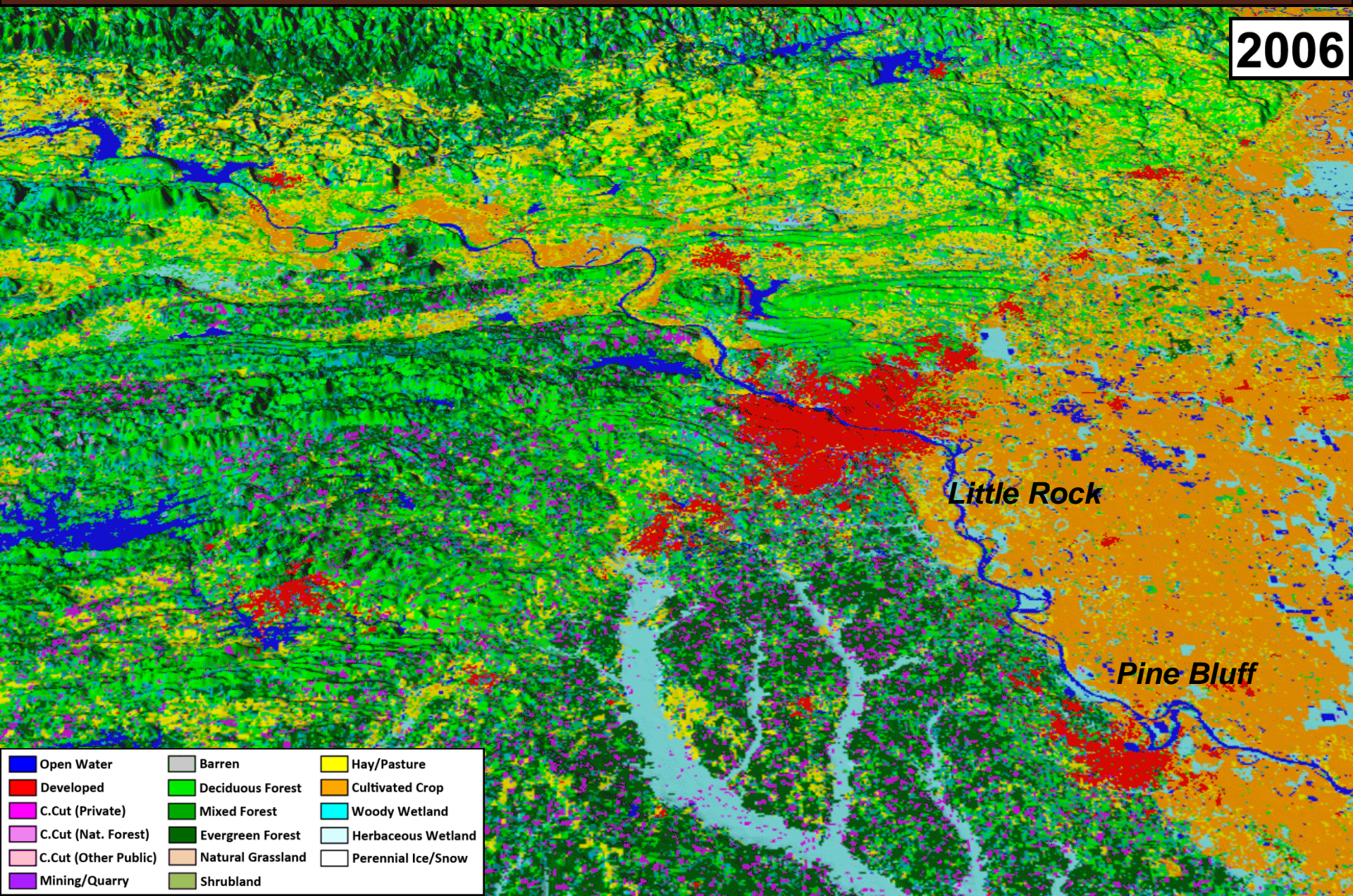


| Patch Library |        |               |
|---------------|--------|---------------|
| Size 1        | Size 2 | Size 3 (etc.) |
|               |        |               |





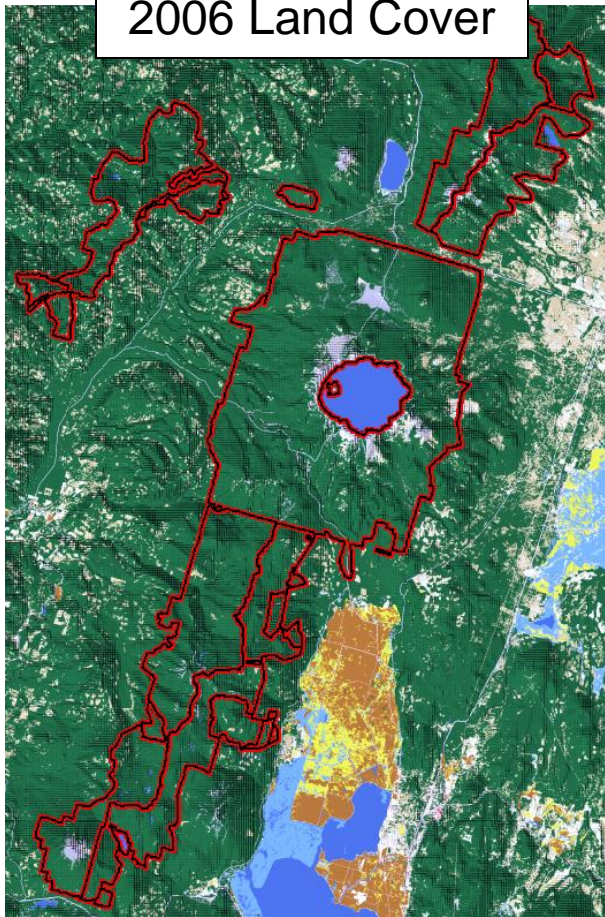
# Completed – Four IPCC SRES Projections for conterminous U.S. 1992 to 2100, 250-meter resolution, 16 LULC classes



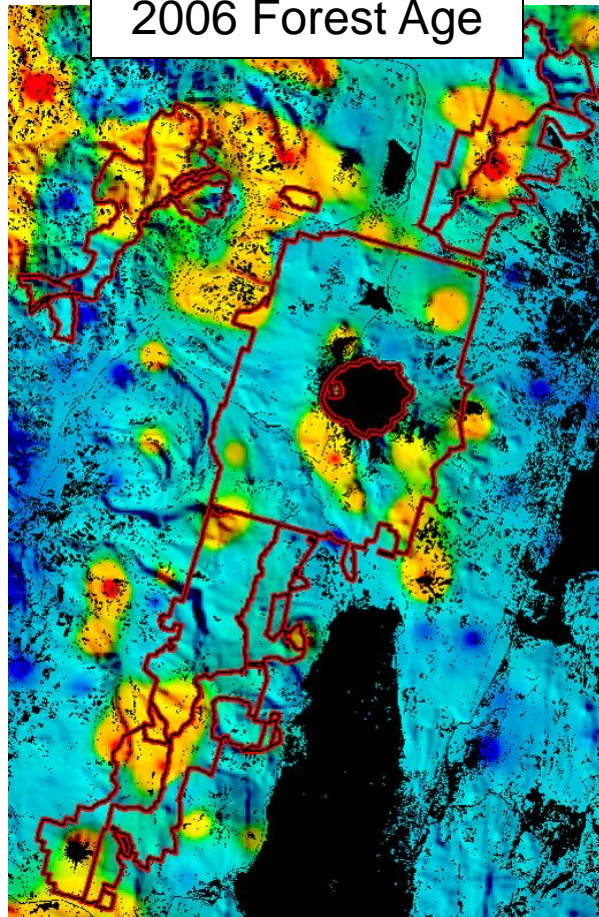


# FORE-SCE – Stand Age and Protected Lands

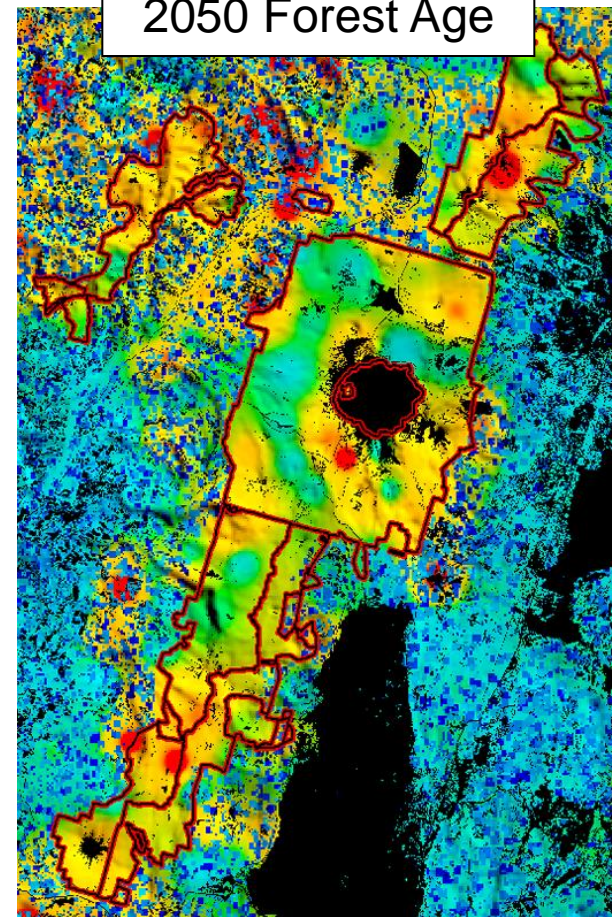
2006 Land Cover



2006 Forest Age



2050 Forest Age



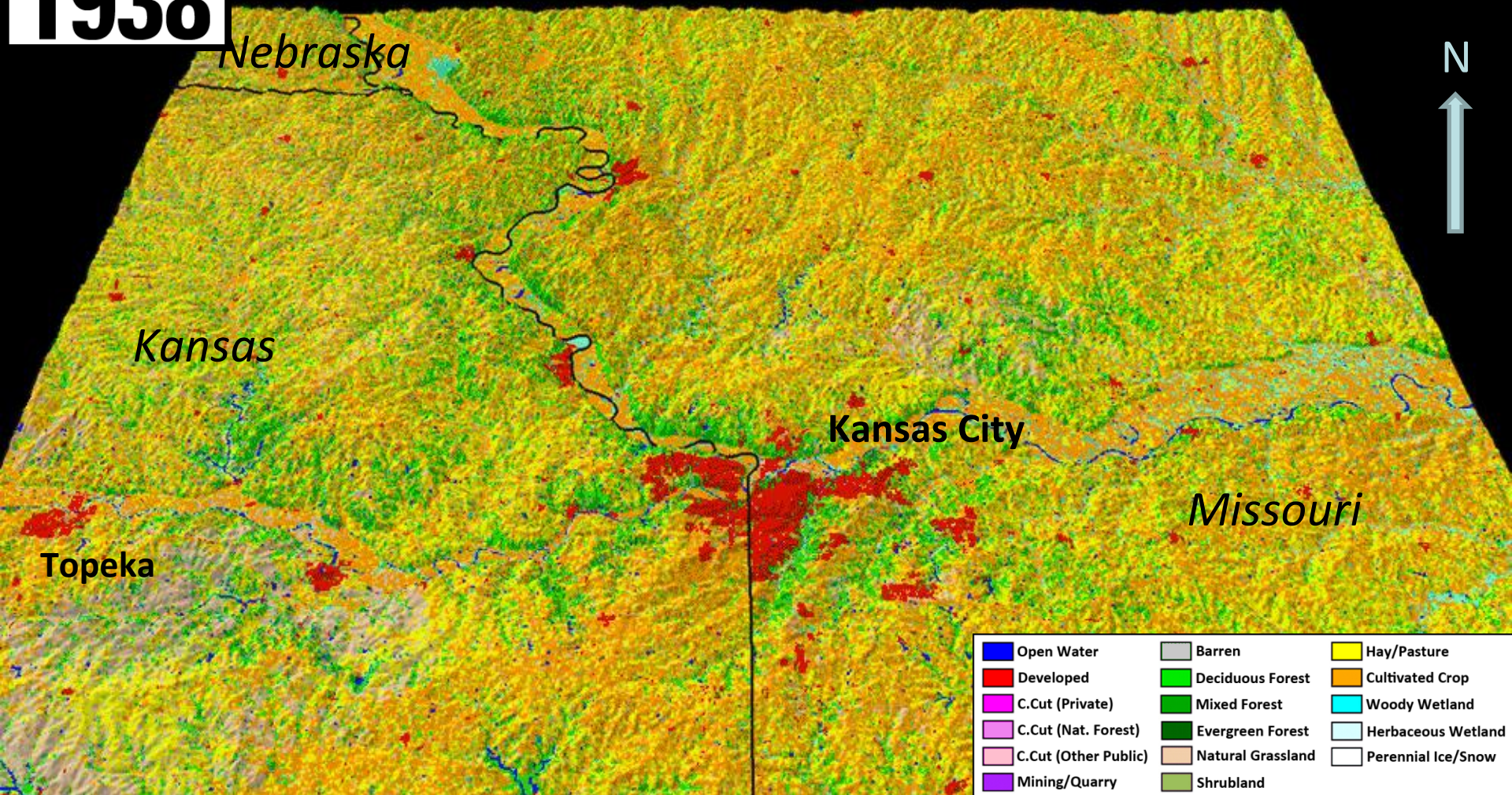
Forest Age - Years





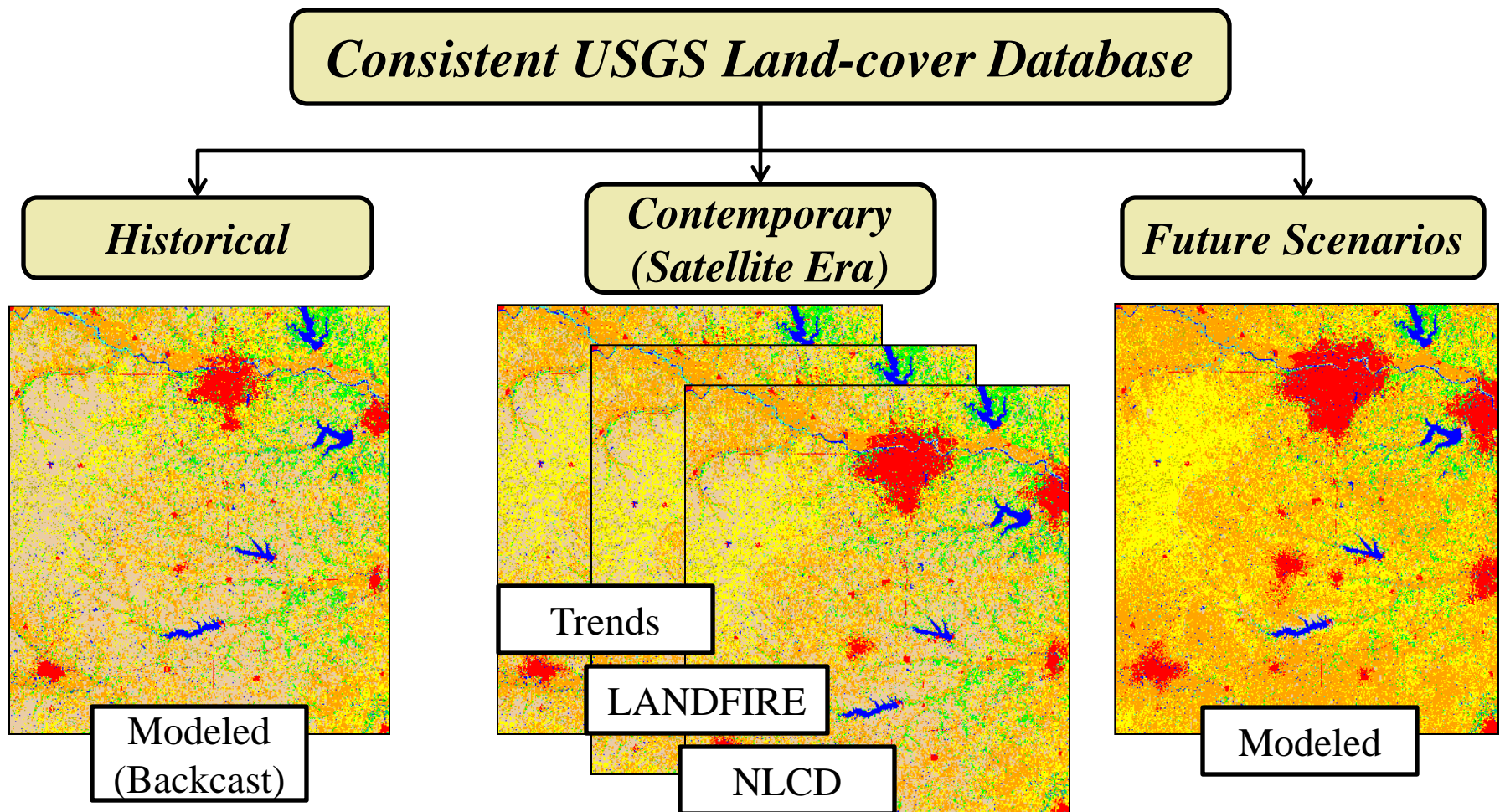
# Historical – Projected Land-cover Database – 1938 to 2100

1938





# USGS Role - Consistent Land-cover Databases: Historical, Current, and Projected Land-cover



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# RAMS/LEAF2/GEMTM Climate Modeling

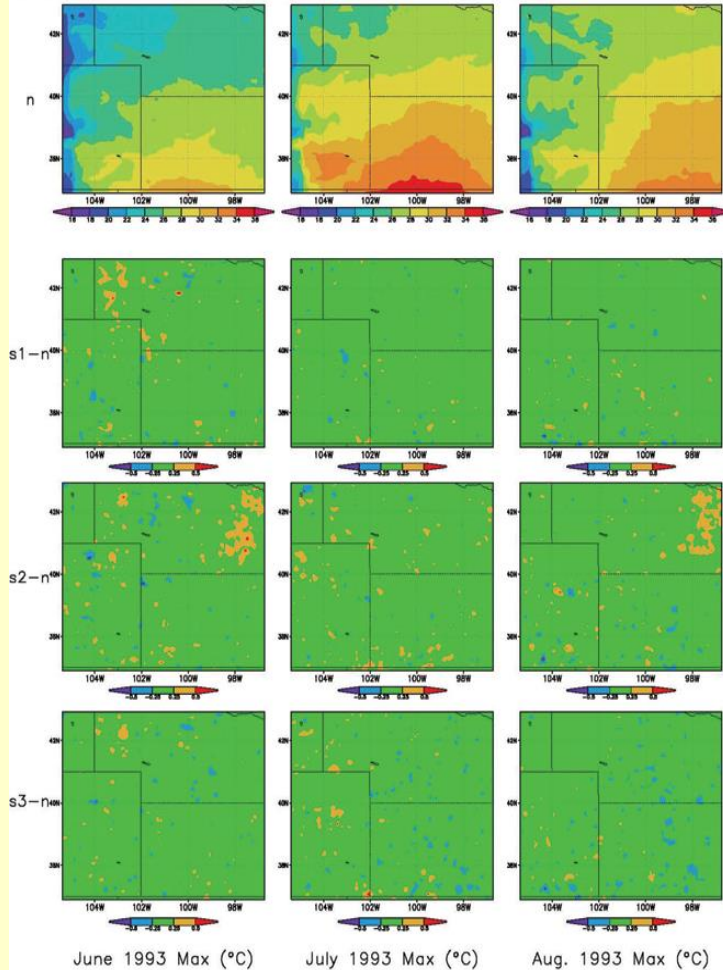
Averaged maximum monthly air temperature shown

1992 NLCD  
baseline run

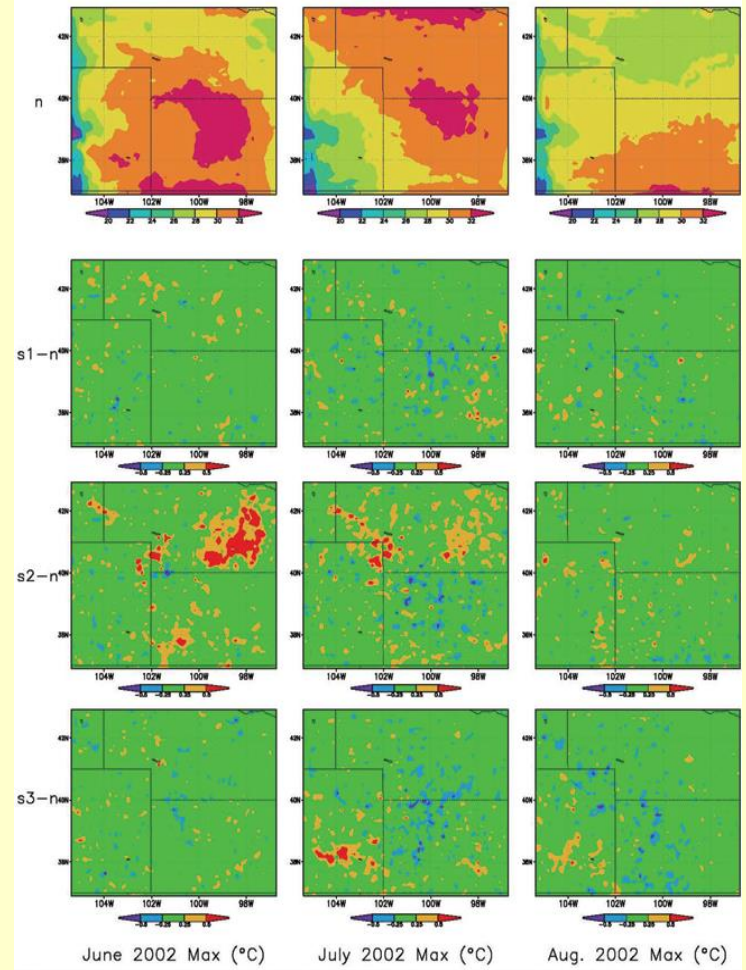
Trends  
extrapolation  
scenario

Agricultural  
decline  
scenario

Agricultural  
expansion  
scenario

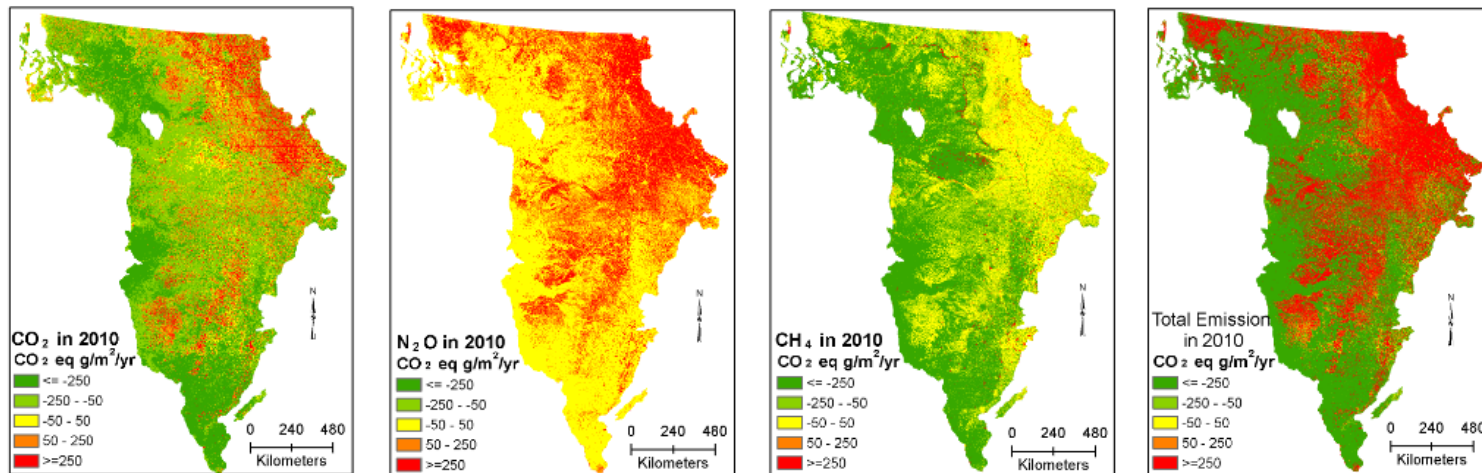
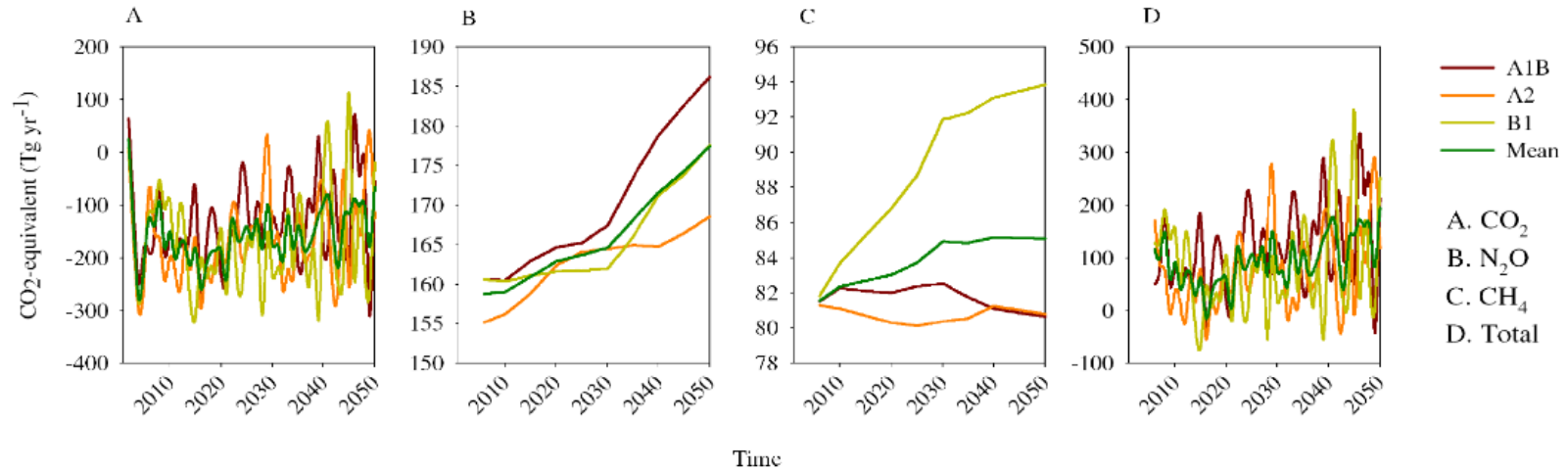


“Wet” year (1993)



“Dry” year (2002)

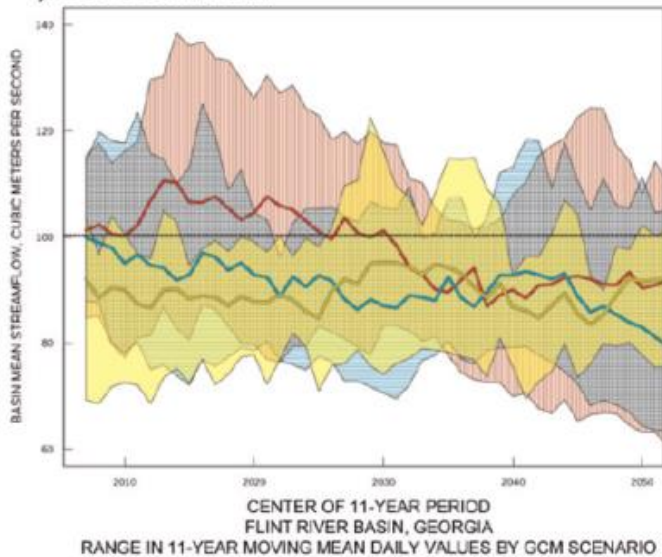
# Global Warming Potential of GHGs



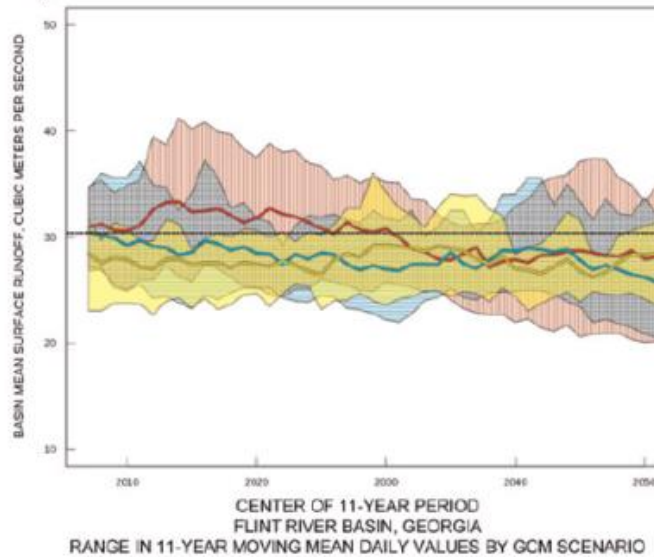


# Hydrologic Impacts of Projected LULC Change

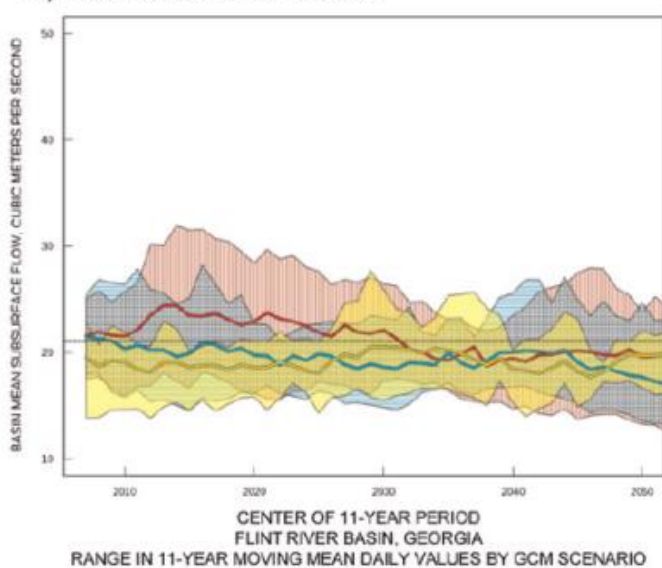
## A) Streamflow



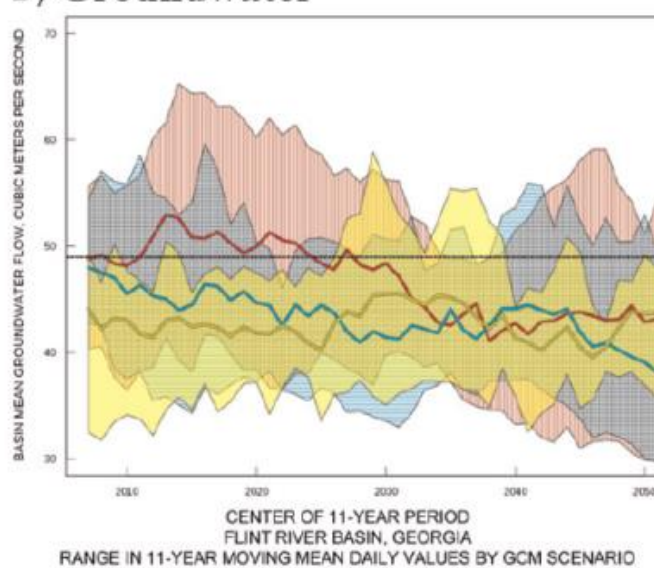
## B) Surface Runoff



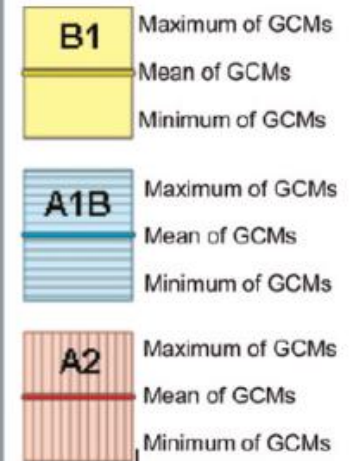
## C) Subsurface Flow



## D) Groundwater

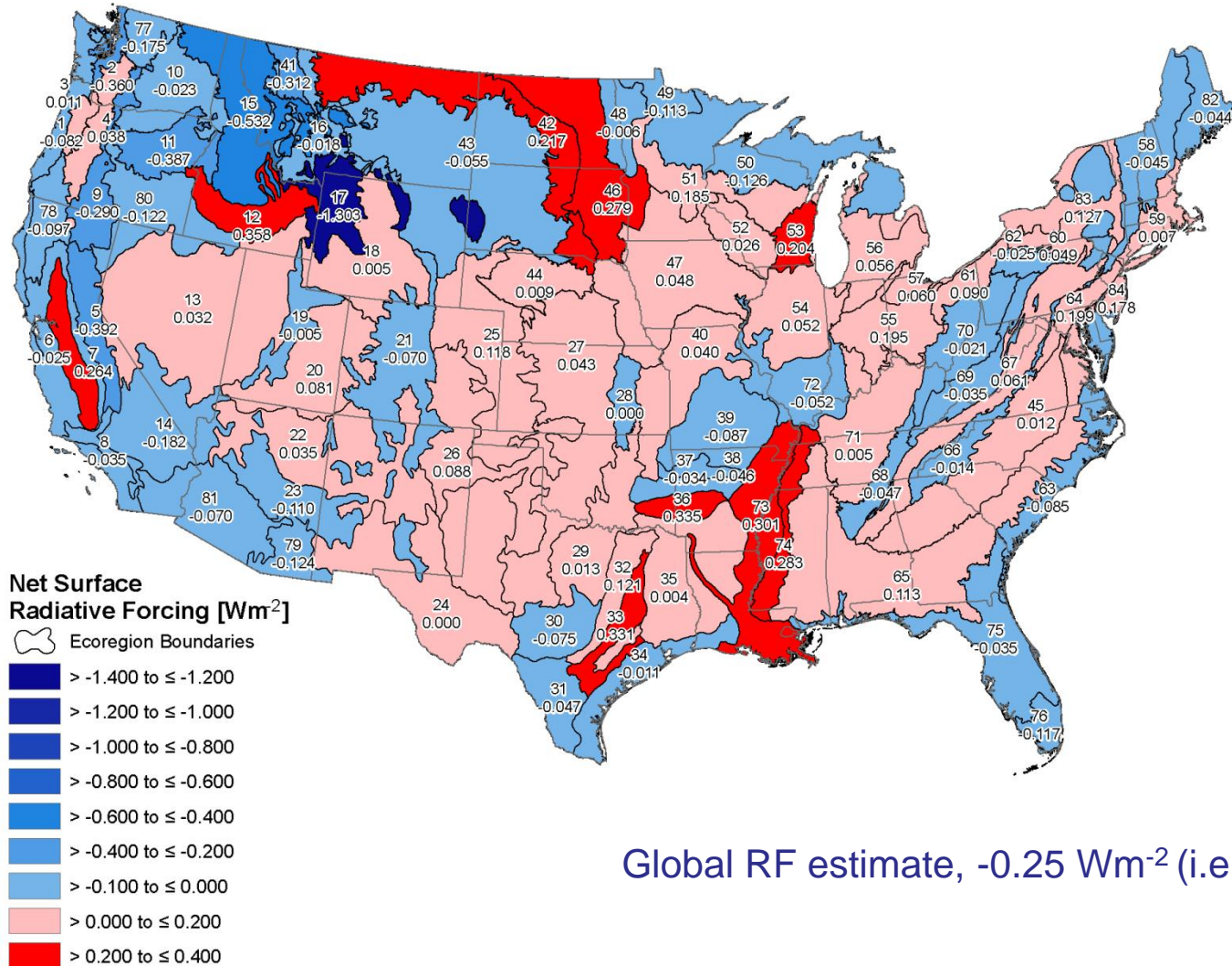


### SRES Scenario



# Impacts of LULC Change on Radiative Forcing

- Found a large regional variation in radiative forcing due to LCU albedo change, varying from **-1.303 Wm<sup>-2</sup>** (Middle Rockies) to **0.358 Wm<sup>-2</sup>** (Snake River Basin)



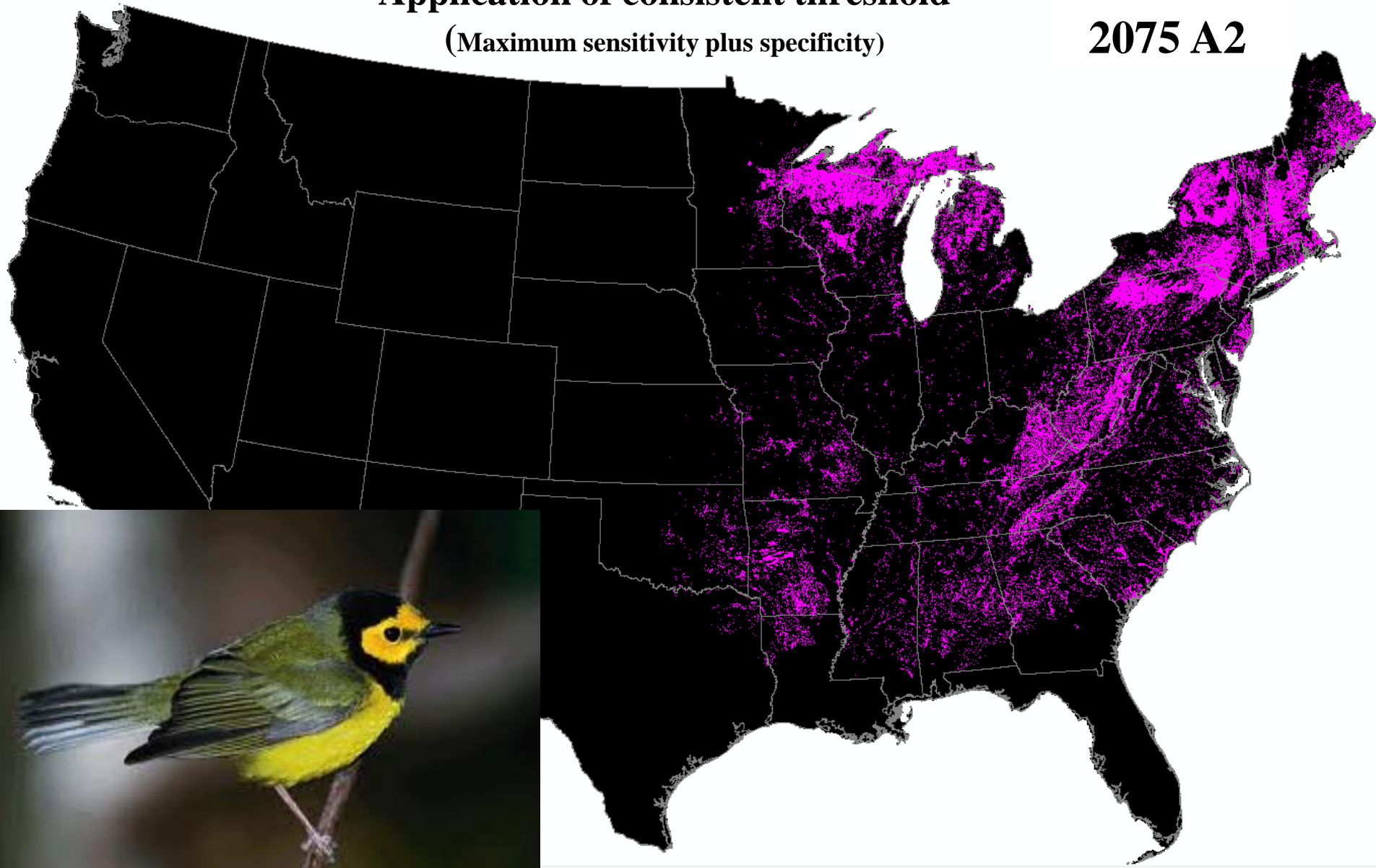


# Hooded Warbler – 2001 to 2075 Range (3 Scenarios)

Application of consistent threshold

(Maximum sensitivity plus specificity)

2075 A2



# Two-pronged approach to LULC Modeling

- **USGS EROS strength has been regional- to national-scale land cover mapping (NLCD, Landfire, etc.)**
- **LULC scenarios and spatial projections produced for Landcarbon are consistent with this scale of focus**
- **Focus #1 – Continued development of periodic LULC projections based on latest suite of global climate scenarios**
  - “Standardized” LULC projections, consistent with downscaled assumptions from accepted global climate scenarios, facilitate ecological assessments that can be compared across scales and different geographic regions.
  - A valuable product, however it’s obvious there is no “one-size-fits-all” in the scenario/LULC modeling stakeholder group.

Ecosystems ♦ Climate ♦ Energy and Minerals ♦ Natural Hazards ♦ Environment and Human Health ♦ Water





# Two-pronged approach to LULC Modeling

- **Focus #2 – Development of flexible, powerful, yet user-friendly LULC modeling tool that enables stakeholders to develop their own, custom LULC projections to suit their unique application**
- **Framework Components**
  - **Stakeholder workshops** – gather aggregate stakeholder needs for such a framework
  - **LULC model** – Model capable of modeling multiple resolution (spatial, thematic, and temporal), as well as the complete suite of potential landscape changes
    - Not only anthropogenic (land-use) change, but also natural vegetation succession, fire, and climate-induced vegetation shifts.
    - Multi-tier modeling framework being built, with land-use modeling, fire, and natural vegetation models running simultaneously
  - **Web-based Resources**
    - Data – LULC data, supporting independent variables, ownership, climate, etc.
    - Other Resources – Model documentation, user discussion, user-created resources (probability surfaces, other data layers, etc.)

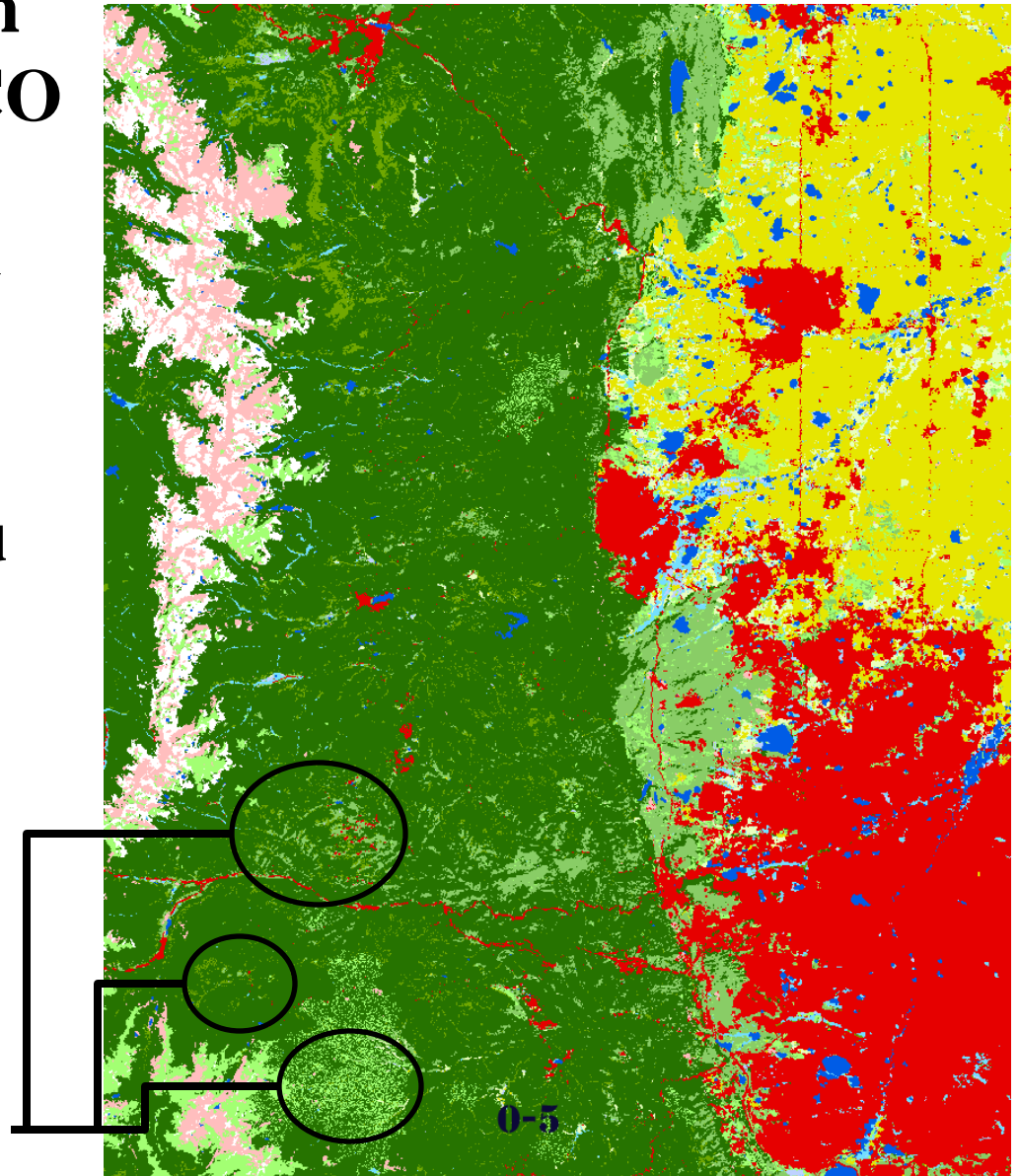
# CHANGE Simulations of Broad LULC Classes in the Vicinity of Denver, CO

Projections from 2010  
(Simulation Year 0) through  
2045 (Simulation Year 45)

Captures both anthropogenic  
(land use – *FORE-SCE*) and  
natural change (fire, veg  
succession, etc. - *LADS*)


- Red – Developed
- Yellow – Agriculture
- Green – Natural Vegetation
- White/Pink – Snow and Rock
- Blue – Water and Wetlands

*Fire and corresponding  
vegetation succession*





# http://landcover-modeling.cr.usgs.gov



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### Why is Land-cover Modeling Important?

Urban development, forestry, agriculture, mining, and other land uses can substantially alter the Earth's surface. Land use and the resultant change in land cover have important effects on ecological systems and processes.

Projecting future land-cover change allows for the optimization and mitigation of potential consequences on numerous ecosystem processes such as biodiversity, water quality, and climate. See the [Applications](#) page for more information on potential uses for modeled land-use and land-cover data.

## Land-cover Modeling at USGS Earth Resources Observation and Science (EROS) Center

USGS scientists have a long tradition of providing high-quality, consistent, and relevant land-cover data for the United States, using our archive of current and historical remote sensing data. [The National Land Cover Database \(NLCD\)](#) provides consistent, spatially explicit, periodically updated maps of land cover for the United States, with mapped dates for 1992, 2001, 2006, and 2011 (in progress). [The USGS Land Cover Trends project](#) has mapped and analyzed historical land-cover change from 1973 to 2000 using the Landsat satellite image archive. [The Landscape Fire and Resource Management Planning Tools Project \(LANDFIRE\)](#) provides multiple landscape attributes to support land managers and modelers. Together, these data provide a suite of data and information on current and recent historical land-cover change for the United States.

Scientists at EROS are using their experience in mapping land cover and their knowledge of land-cover change processes to temporally extend these databases beyond the dates of available remote sensing data. Using the EROS FOREcasting SCEnarios of Land-Cover (FORE-SCE) model, EROS scientists are modeling land-cover change both into the future, using scenario-based modeling approaches, and for "backcasting" land cover for historical periods. In combination with USGS remote sensing based land-cover data, EROS' modeling efforts result in consistent, annual land-cover maps from 1938 through 2100, with multiple scenarios of potential land cover for future periods.

### Modeling Examples

- » [Bismarck, North Dakota - A1B Scenario](#)
- » [Washington / Baltimore Area - A2 Scenario](#)

2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

